EFFECT OF YOGA THERAPY ON AUTONOMIC FUNCTION AND BIOCHEMICAL PARAMETERS IN PATIENTS WITH HYPERTENSION - A RANDOMISED CONTROLLED TRIAL

SYNOPSIS OF THESIS

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PUDUCHERRY

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CERTIFICATE

This is to certify that the synopsis of the thesis titled "**Effect of yoga therapy on autonomic function and biochemical parameters in patients with hypertension - A randomised controlled trial"** submitted for the Degree of Doctor of Philosophy in the Faculty of Medicine, Sri Balaji Vidyapeeth is a bonafide work done by **P Uthiravelu, UIN. No. 1505001002**, Department of physiology, Mahatma Gandhi Medical College & Research Institute, Puducherry – 607402, during the period from October 2015 to May 2024 under my guidance and supervision. This research work is original and has not been submitted elsewhere for the award of any other Degree or Diploma or Associateship or Fellowship or any other similar titles**.**

Dr. Vasanthan, PhD
Supervisor and Guide

Date: 29 May 2024

Place: Puducherry

Declaration

I hereby declare that the synopsis of the thesis titled "**Effect of yoga therapy on autonomic function and biochemical parameters in patients with hypertension - A randomised controlled trial"** submitted for the Degree of Doctor of Philosophy in the Faculty of Medicine is my original work and the dissertation has not formed the basis for the award of any degree, diploma, associate ship or fellowship of similar other titles. It has not been submitted to any other university or institution for the award of any degree or diploma.

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PhD scholar

Date: 29 May 2024

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Table of contents

S:No	Contents	Page number
1	Introduction	1 - 4
2	Review of literature	5 - 7
3	Aim and objective	8
4	Methodology	9 - 12
5	Results	13 - 18
6	Discussion	19 - 21
7	Conclusion	22
8	References	23 – 28
9	Publications and presentations	29

Introduction

Salutogenesis:

It was introduced by Aron Antonovsky in 1996 which focuses primary on factors supporting human health and well being rather than the usual focus on risk factors and diseases. It is concerned with the relationship between health, stress and coping. Achieved by person's sense of coherence (SOC). It is Capacity to understand the situation (meaningfulness), Deal in health promoting direction (comprehensibility), Capacity to do so (manageability).

Modern man is the victim of stress and stress disorders including hypertension. Being holistic in nature, yoga is very effective in preventing as well as managing these disorders (Vijayalakshmi P. et al, 2004). The effectiveness of yoga is due to its ability to produce deep psychosomatic relaxation (Madanmohan et al, 1992) and improve physiological functions (Madanmohan et al, 2003). Yoga is a technique that helps in coordination between mind and body. Many studies have the therapeutic potential of yoga in various disease such as hypertension, diabetes mellitus and coronary arterial disease (Innes KE et al,2005, Madanmohan et al, 2004, Cohen DL et al,2001, Yogendra J et al, 2004 and Raghuraj P, et al, 2008).

Hypertension is a long-term lifestyle disorder that causes major health problems for the community. Directly it causes 50% of coronary heart disease and causes two-thirds of heart failure and stroke (CDC,2011). Hypertension is a chronic elevated blood pressure that is systolic blood pressure 140mmHg or above and diastolic blood pressure 90 mmHg or above (JNC7 2003). An enhanced workload of heart can be damage the cardiac muscle and vales of

heart which cause heart failure (Salome P., 2013). Hypertension is characterized by diminished heart rate variability due to Sympathovagal imbalance (Pavithiran et al, 2008).

Dyslipidemia is a habitual metabolic abnormality found in hypertensive patients. Hypertension and dyslipidemia causes endothelial dysfunction, vascular inflammation, vascular remodeling, and atherosclerosis (Petrie JR et al, 2018).

Oxidative stress: Imbalance between Reactive oxygen species (ROS) & antioxidant defense systems. (Masanori et al,2001 & Ceconi et al, 1992). ROS - pathophysiological role in hypertension. Due to O^- excess (oxidative stress) and decrease in Nitric oxide (NO) availability in vasculature, kidney and ROS-mediated cardiovascular remodeling. (Kishi T et al 2004). Endogenous antioxidant enzymes SOD act opposite to the oxidative damage. (Cathcart MK et al, 2004)

Yoga, is complimentary therapeutic regiment to be useful to individuals with a wide range of health conditions, including cardiovascular diseases (CVDs) and diabetes (Bijlani RL et al, 2005, Ravinder et al, 2005 and Birdee GS et al, 2008). Yoga could contribute to low blood pressure and reduces risk factors of hypertension (Okonta N et al, 2012, Yang K 2007, Mizuno J et al 2013). Autonomic nervous system is important in maintenance of normal blood pressure and imbalance of autonomic function contributes to the pathogenesis of hypertension and yoga restores sympathovagal balance (Sevre K et al, 2001).

Hypertension is a major risk factor contributing to the global burden of cardiovascular disease and its incidence in India is increasing as that of developed countries. The present estimate of 11.8 crore hypertensive in India is anticipated to double by 2025. A large number of patients

are on life-long drug therapy imposing a huge economic burden and undesirable side effects of drug therapy

Yoga is the best lifestyle ever designed. It achieves physical, mental, social and spiritual well being. Yoga harmonizes mind and body, reduces stress through relaxation contributing to salutogenesis & enhancing person's SOC. It has major role in prevention, management and rehabilitation in stress induced lifestyle disorders like hypertension (Gupta, 2004; Madanmohan, 2002; Goyal, 2006). Eight limbs of Ashtanga Yoga – pranayams and asans are practiced commonly and as therapy.

Yoga has the potential to prevent progression of the condition and it started early, effect cure. We have reported that new onset hypertension is characterized by diminished short-term heart rate variability as a result of altered sympatho-vagal balance (pavithiran et al, 2008). Essential hypertension is a risk factor for stroke, congestive heart failure, arterial aneurysm, myocardial infarction and chronic renal failure (Hackam DG et al, 2010 and pierdomenico SD et al, 2009). If started at an early stage, yoga can prevent the progression of hypertension (Pavithiran et al, 2008).

Oxidative stress caused by increase in the production of reactive oxygen species (ROS) such as superoxide radicals (O_2), hydrogen peroxide (H_2O_2), hydroxyl radicals (OH), and singlet oxygen. ROS are produced within the cell in the multiple compartments but majority of ROS are generated in the mitochondria during ATP production by oxidative phosphorylation contributing to aging and age-related disorders. Our body has complex antioxidant defence mechanism to prevent the deleterious effect of ROS. An imbalance between reactive oxygen species (ROS) and antioxidants causes oxidative stress (Masanori et al,2001 & Ceconi et al,

1992). Endogenous antioxidant enzymes SOD act opposite to the oxidative damage. (Cathcart MK et al, 2004)

Pranayam: deep, rhythmic, uniform and conscious breathing technique

Asan: steady and comfortable posture with conscious.

Yoga enhances the endogenous antioxidants such as SOD, Catalase, and glutathione peroxidase (GSH-Px) which act as a primary line of defence mechanism against the ROS toxic effects. (Li H et al 2013)

If started early, yoga can prevent progression/ cure hypertension. (Pavithiran et al, 2008).

Review of literature

All over the world, non-invasive monitoring of heart rate variability as an index of autonomic status in hypertension is an accepted norm (Guzzetti et al, Huikuri et al and Langetwitz et al). Autonomic nervous system plays an important role in the development of essential hypertension. Hypertension is associated with autonomic dysregulation characterized by sympathetic overactivity and/or attenuation of vagal modulation of heart rate. A 5 min ECG recording to compute short-term HRV is a standard method for assessing the autonomic regulation of SA node (Task force report). The Framingham heart study has provided evidence of reduced HRV in subjects with new-onset hypertension (Singh et al.).

Since HRV is relatively inexpensive measurement that requires little cooperation from the subject. It is gaining popularity in our country also. In a recent study, they have reported that 12 week yoga therapy improves HRV in subjects with hypertension (Pushpanathan et al. 2015). In an early study (Pavithran et al. 2008) they have found decreased HRV and elevated oxidative stress in subjects with newly diagnosed essential hypertension. Yoga training is very effective in reducing HR, SBP, DBP and RPP in hypertensive patients due to normalisation of autonomic cardiovascular function resulting in increased modulation and decreased sympathetic activity and improving baroreflex mechanism (Gupta L et al. 2013).

In a recent study, researchers have reported that 3 months yoga, Asanas along with Pranayama technique significantly decrease SBP and DBP (Gadham et al. 2015). Twelve week yoga therapy significantly improves parasympathetic activity and decrease sympathetic activity in heart failure patients (Krishna BH et al. 2014). Another study have reported the influence of twelve week yoga therapy in the improvement of cardiac autonomic function in patients with

essential hypertension, if practiced regularly along with other lifestyle modifications and drugs (Punitha et al. 2011). A short-term yoga program for the patient to practice at home seems to have an antihypertensive effect, as well as a positive effect on self-rated quality of life compared to controls (Wolff et al. 2013). Yoga therapy has potential to enhance the beneficial effects of essential Hypertension and can be used as an effective complementary or integrative therapy programme (Madanmoham et al.2013).

Based on scientific research, Non-invasive monitoring of HRV is an index of autonomic status in hypertension (Guzzetti et al 1998, Huikuri et al 1996, Langetwitz et al 1994). The Framingham heart study has provided evidence of reduced HRV in subjects with hypertension (singh et al 1998). Six month yoga training improves HRV in normal subjects (Vasanthan et al. 2017). Yoga training was effective in decrease HR, SBP, DBP and RPP in hypertensive patients due to normalisation of autonomic cardiovascular function (Gupta et al. 2013). 12-week yoga program was an effective intervention in reducing BP, HR, BMI, anxiety, and perceived stress in hypertensive patients (Sujatha T et al. 2014). Silver yoga decrease the BP indices in 124 geriatric subjects (Bhawanani et. al., 2015). Shavasan for 15 minutes decreases SP & DP in hypertensive patients (Santaella, 2014). Immediate effect of chandra nadi pranayama (left unilateral forced nostril breathing) was effective in reducing HR and SP in hypertensive patients on regular standard medical management (Bhawanani AB et al., 2012).

Yogic asans has been found to correct dyslipidemia which is a modifiable risk factor for coronary heart disease. It has also been found to be effective in reducing heart rate and blood pressure in mild hypertensives (Devi V et. Al ., 2016). Om chanting and Yoga nidra reducing BP and improving lipid profiles in patients with Hypertension (Anjana et al., 2022). Regular

practice of yoga significantly improved the health condition of obese women by decreasing total cholesterol and triglyceride (Malarvizhi et al., 2022). Lifestyle modification program improved cardiovascular risk factors such as hypertension and dyslipidemia along with oxidative stress (Bhatnagar a et al., 2015).

Three months yoga training was found effective to reduced oxidative stress and to improve the antioxidants levels in elderly hypertensive subjects (Patil et. Al., 2014). Pranayam can significantly reduce oxidative stress and significant increase in the level of antioxidant enzymes (Agarwal BK et al., 2015). Regular yoga practice improves antioxidant status, immune function in young healthy people (Lim SA et al., 2015).

Yoga is effective in reducing oxidative stress and improving antioxidant defence in elderly hypertensive subjects (Patil SG et al.2014). Sudarshan kriya yoga on DBP, malondialdehyde adducts kidney function in hypertensive was of counteractive nature and felt to be distinctly different than the effect of drugs (Agte et al. 2011). Increased ROS production has been involved in multiple pathological processes, including hypertension (Harrison and Gongora 2009). There is strong evidence suggesting that elevated blood pressure can promote ROS accumulation in the kidney and thereby further exacerbate hypertension (Harrison and Gongora 2009). Antioxidants as vitamin E, Glutathione peroxidase, or superoxide dismutase (SOD) are decreased in essential hypertensive's (Nakazono *et al).* Short-term Bikram yoga intervention improved arterial stiffness in young adult (Hunter et al. 2013).

Hypothesis:

Does intervention by yoga modify clinical outcome in hypertension?

Null hypothesis:

Asan or Pranayam training will not influence cardiac autonomic function in hypertensive's.

Aim and objectives

- To assess the effect of yoga training on Blood pressure and heart rate variability in subjects with hypertension
- To assess the effect of yoga training on lipid profile and oxidative stress in subjects with hypertension
- To correlate these parameters after12 weeks of yoga training and 12 weeks follow-up
- To compare these parameters with hypertensive's not practising yoga (control).

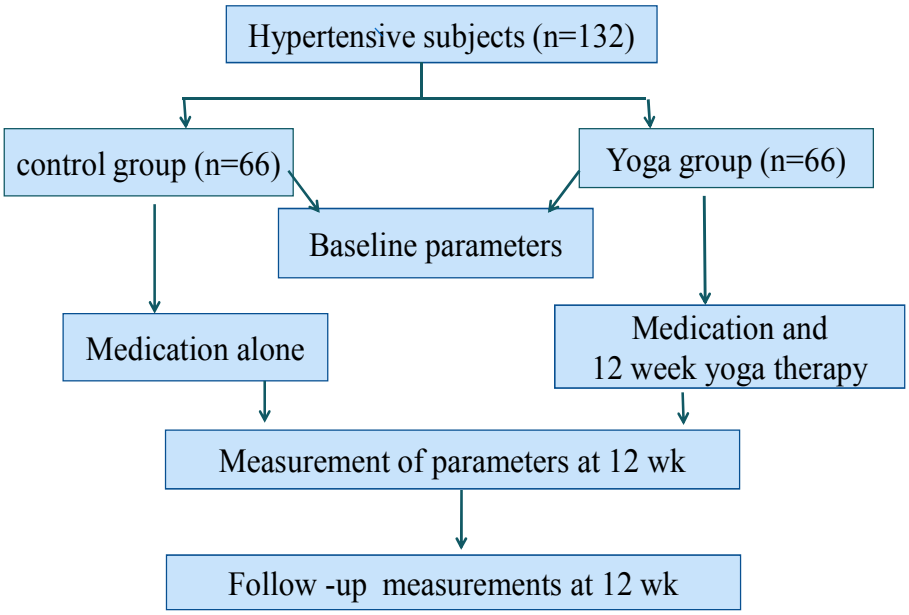
Materials and Methods

Before commencement of the study, Institute Human Ethical Committee (IHEC) approval were obtained. A total number of 132 subjects recruited from medicine OPD and OPD of Yoga Therapy, Education and research (CYTER) have screened for blood pressure (BP). Subjects were excluded based on Alcohol or nicotinic dependence, morbid obesity, secondary hypertension, acute illness, chronic organic disorders like diabetes mellitus, bronchial asthma, renal dysfunction etc. After initial familiarization, subjects having BP > 140/90 mmHg will be randomly assigned to yoga (n=66) or control (n=66) groups. Control group will serve as wait list control, aged between 30-45 years. A total of 45 minutes training program was given for yoga group for 3 days a week for 3 months under our supervision and subject were encouraged to practice the same at home for rest of the weekdays and a yoga performed day record was obtained through phone call. During the study period, more than 80 % attendance was maintained in yoga group to perform yoga. During this period waiting list control group was given study time for group discussion on academic activities.

Study parameters:

Physiological Parameters	**Biochemical Parameters**
Blood Pressure	Lipid profile
Heart rate response to quit breathing	Oxidized LDL (Ox-LDL)
Heart rate variability (Short-term HRV)	Glutathione peroxidase (GPx)
	Superoxide dismutase (SOD), & Catalase

Methodology



Intervention:

- **Yoga therapy (**3 days a week**)** in CYTER

Encouraged subjects to practice at home for rest of weekdays.

Table 1: Module for Yoga therapy

1	Yogic Comforting	
2	Preliminary Practices (5 min)	Coordination for the practice of Breath–body and joint loosening exercises
3	Asans or fixed Postures (20 min)	Talasan, Ardhakati chakrasan, Ardha chakrasan, Uttanpadasan, Ardha halasan, Pavanmuktasan, Makarasan, Bhujangasan and Vajrasan
4	Pranayam or Techniques for Breathing (10 min)	Shavithri, Chandra Nadi, Pranav and Nadi shuddhi pranayama
5	Techniques for Relaxation (10 min)	Shavasan with savitri pranayama

All the parameters were recorded in research lab, Department of Physiology, MGMCRI. Subjects were explained about the method of recording and were familiarized with the laboratory environment. Recordings were obtained between 8 and 10 AM without any stimulants in pre-recording period. The laboratory temperature was maintained at comfortable level with subdued lighting.

Recording of heart ate variability (HRV):

Subjects were made in supine position on couch and allowed to relax for 10 min. Lead II ECG and respiration were recorded at the 500 samples per sec by using INCO Polyrite-D for 5 min. R-R interval data were extracted by RMS polyrite software, then HRV was analyzed from R-R interval by Kubios HRV, version 2.0, Department of Physics, University of Kuopio, Finland. HRV data analysis and signal processing followed guidelines defined by "Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology" (Task Force, 1996).[25]

Time domain components consisted mean HR, mean RR, standard deviation of RR intervals (SDNN), square root of the mean of the sum of the squares of differences between adjacent RR intervals (RMSSD),adjacent RR interval differing more than 50 ms (NN50), and NN50counts divided by all the RR intervals (pNN50).

Frequency domain components consisted very low frequency (VLF) component (0.003 to 0.04 Hz), low-frequency (LF) component (0.04 to 0.15 Hz), and high-frequency (HF) component (0.15 to 0.5 Hz) and LF/HF ratio; the ratio of LF power to HF power, low frequency power in normalized units (LF nu) = (LF x 100) / (TP–VLF), and similarly HF nu was calculated. HF,

HF nu, SDNN, RMSSD, NN50, and pNN50 reflect cardiovagal tone; LF reflects both the sympathetic and parasympathetic tones; VLF component's interpretation is not clear, and it cannot be interpreted using short-term HRV recordings; LF nu and HF nu represent a relative tone of sympathetic and parasympathetic nervous system (PSNS).

Recording of blood pressure:

After 15 min of rest in supine, SBP and DBP were obtained from the subjects by using sphygmomanometer. The average of 3 trials with 5 minutes interval were taken for our calculation. Pulse pressure was determined by PP = SBP – DBP. MAP and RPP were determined by using respective formulae, MAP = DBP + (PP/3); RRP = (HR x SBP)/100.

Biochemical parameters technique:

S. No	**Parameters**	**Technique**
	Lipid profile	
1	Cholesterol	CHOD-PAP enzymatic photometric test
2	TGL	Colorimetric enzymatic test using glycerol-3-phosphate-oxidase (GPO)
3	HDL	Calorimetric method
	Stress marker	
1	Oxidized LDL	ELISA
	Endogenous anti-oxidants	
1	SOD	ELISA
2	GSH-Px	Calorimetric method
3	Catalase	Calorimetric method

Results

Baseline characters of control and yoga group

Parameters	Control group (n=63)	Yoga group (n=61)
Age (Mean ± SD)	40.97 ± 5	39.52 ± 4.04
Male	32	36
Female	31	25
Vegetarian	11	10
Non-vegetarian	52	51
Medications		
Calcium channel Blocker	52	56
Angiotensin receptor blocker	5	2
Angiotensin receptor blocker & diuretic	6	3

Anthropometric baseline parameters

Parameters	Control group (n=63)	Yoga group (n=61)	P value
Weight (Kg)	67.3 ± 12.5	73.2 ± 17.4	0.19
Height (Cm)	165.15 ± 7.7	168.5 ± 10.3	0.20
BMI	24.5 ± 3.5	25.6 ± 5.37	0.42

Effect of 12 weeks yoga practice followed by 12 weeks follow-up on RPP, HR, PP, SBP, MAP and DBP on hypertensive patients

Parameters	Control (N= 63)			Yoga (N= 61)		
	Pre	Post	Follow-up	Pre	Post	follow-up
HR	77.63 ± 4.87	77.8 ± 3.51	78.4 ± 3.23	81.94 ± 4.56	75.29 ± 4.11$^{\#\#\#}$**	80.01 ± 5.21$^{\$\$\,\beta}$
SBP	135.14 ± 7.52	134.44 ± 6.21	134.51 ± 5.42	137.38 ± 9.21	129.77 ± 8.38$^{\#\#\#}$***	133.57 ± 6.64$^{\$\$\$\,\beta\,\beta\,\beta}$
DBP	90.76 ± 6.11	88.70 ± 5.97	88.57 ± 5.07	90.36 ± 6.30	87.93 ± 5.38$^{\#}$***	88.46 ± 6.51 $^{\beta\,\beta\,\beta}$
PP	44.38 ± 4.65	45.75 ± 5.35	45.94 ± 5.36	47.02 ± 4.21	41.84 ± 5.04$^{\#}$***	45.11 ± 5.26$^{\$\$\$\,\beta\,\beta}$
MAP	105.56 ± 6.24	103.95 ± 5.50	103.88 ± 4.54	105.67 ± 7.12	100.54 ± 6.09$^{\#\#}$***	103.50 ± 11.07$^{\$\$\$\,\beta\,\beta\,\beta}$
RPP	106.66 ± 14.37	104.99 ± 13.89	105.102+13.3	110.38 ± 14.33	100.81 ± 4.17$^{\#}$***	103.16 ± 13.65$^{\$\$\,\beta\,\beta\,\beta}$

SBP- Systolic Blood pressure, DBP- Diastolic blood pressure, PP- Pulse pressure, MAP- Mean arterial pressure, RPP- Rate pressure product. $^{\#}p < 0.05$; $^{\#\#}p < 0.01$; $^{\#\#\#}p < 0.001$ comparison between post control and post yoga group by unpaired t-test. *p < 0.05; **p < 0.01; ***p < 0.001 comparison within the group with pretraining and post training by using RMANOVA; $^{\$}p < 0.05$; $^{\$\$}p < 0.01$; $^{\$\$\$}p < 0.001$ comparison between post yoga and follow-up yoga group by RMANOVA. $^{\beta}p < 0.05$; $^{\beta\,\beta}p < 0.01$; $^{\beta\,\beta\,\beta}p < 0.001$ comparison between pre yoga and follow-up yoga group by RMANOVA.

The means of SP, DP, PP, MAP, and RPP of pre, post, and follow-up values of the control group were compared by RM ANOVA and it was found that also there is no significant difference exists among the groups. In test group, the mean values of post-training and follow-up show a significant decrease when compared with pre-training values. There are a significant decrease in test group post-training and follow-up values when compared with post-training and follow-up values of control group values respectively. There are a significant increase in test group follow-up values when compared with test group post-training.

Effect of intervention and follow-up on HRV (Time domain parameters) on hypertensive patients

Parameters	Control (N= 63)			Yoga (N= 61)		
	Pre	Post	Follow-up	Pre	Post	Follow-up
HR	72.49 ±5.74	71.87 ± 5.64	72.92 ± 8.17	73.41± 7.81	69.31 ± 6.54$^{\#***}$	71.57 ± 8.31$^{*\$\$\beta}$
Mean RR	779.01±98.3	774.59±85.49	786.57±93 .38	767.67±82 .81	829.53±10 2.34$^{\#\#\#***}$	841.77±123. 76$^{***\beta\beta\beta}$
SDNN	33.21 ± 13.38	34.27 ± 7.43	33.34 ± 6.99	31.47 ± 8.87	37.64 ± 9.67$^{\#***}$	36.50 ± 9.92$^{***\beta\beta\beta}$
RMSSD	26.49 ± 10.56	27.38 ± 10.79	26.84 ± 11.72	24.73 ± 6.98	27.71 ± 7.25***	26.50 ± 8.04$^{*\beta}$
PNN50	9.03 ± 4.19	9.21 ± 4.32	9.32 ± 4.28	8.58 ± 3.41	10.10 ± 4.59*	10.39 ± 4.65$^{**\beta\beta}$

$^{\#}p < 0.05$; $^{\#\#}p < 0.01$; $^{\#\#\#}p < 0.001$ comparison between post control and post yoga group by unpaired t-test. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$ comparison within the group with pretraining and post training by using RMANOVA; $^{\$}p < 0.05$; $^{\$\$}p < 0.01$; $^{\$\$\$}p < 0.001$ comparison between post yoga and follow-up yoga group by RMANOVA. $^{\beta}p < 0.05$; $^{\beta\beta}p < 0.01$; $^{\beta\beta\beta}p < 0.001$ comparison between pre yoga and follow-up yoga group by RMANOVA.

There was no significant difference in the control group in the time domain parameters of HRV in the pre intervention, post intervention and post follow-up. In the yoga group, time domain parameters were significantly increased after intervention and after follow-up when compared with the pretraining values. The yoga group post training parameters showed significant increase compared to control group.

Effect of intervention and follow-up on HRV (Frequency domain parameters) on hypertensive patients

Parameters	Control (N= 63)			Yoga (N= 61)		
	Pre	Post	Follow-up	Pre	Post	Follow-up
LF	551.585 ± 255.32	545.905 ± 242.622	571.143 ± 239.03	555.492 ± 164.95	498.115 ± 207.95	506.738 ± 236.82
HF	163.142 ± 47.15	165.683 ± 43.35	163.937 ± 45.44	158.951 ± 45.56	206.033 ± 51.75$^{###***}$	174.885 ± 51.89$^{\$\$\$}$
Total Power	1111.314 ± 320.05	1110.302 ± 332.32	1132.825 ± 326.85	1135.541 ± 223.71	1138.41 ± 270.38	1092.18 ± 293.33
LF/HF	3.662 ± 2.09	3.563 ± 1.97	3.726 ± 1.91	3.743 ± 1.33	2.553 ± 1.16$^{###***}$	3.217 ± 2.08$^{\$}$
LF nu	49.568 ± 22.83	53.037 ± 19.27	51.806 ± 20.57	60.449 ± 16.45	50.02 ± 21.69***	52.703 ± 20.66$^{*\beta}$
HF nu	50.426 ± 22.43	46.963 ± 19.27	48.194 ± 20.57	39.551 ± 16.26	49.98 ± 21.69***	47.297 ± 20.66$^{*\beta}$

$^{\#}p < 0.05$; $^{\#\#}p < 0.01$; $^{\#\#\#}p < 0.001$ comparison between post control and post yoga group by unpaired t-test. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$ comparison within the group with pretraining and post training by using RMANOVA; $^{\$}p < 0.05$; $^{\$\$}p < 0.01$; $^{\$\$\$}p < 0.001$ comparison between post yoga and follow-up yoga group by RMANOVA. $^{\beta}p < 0.05$; $^{\beta\beta}p < 0.01$; $^{\beta\beta\beta}p < 0.001$ comparison between pre yoga and follow-up yoga group by RMANOVA.

Frequency domain parameters of HRV:

There was no significant difference in the HRV frequency domain parameters of pre, post, and follow-up values of the control group. In yoga group, the post training mean values of HF shows significant increase and LF/HF ratio shows significant decrease when comparing with post training control values. Post training yoga group mean values of HF and HF nu shows significant increase and LF/HF ratio, LF nu shows significant decreases compared with pre training yoga group.

Biochemical parameters.

Lipid profile parameters

Parameters	Control (N= 63)			Yoga (N= 61)		
	Pre	Post	Follow-up	Pre	Post	follow-up
Cholesterol	167.82 ± 18.58	166.89 ± 17.96	167.05 ± 17.49	170.90 ± 19.21	165.19 ± 18.83**	166.92 ± 19.68$^{\beta}$
TGL	143.38 ± 12.08	144.57 ± 12.86	144.00 ± 10.651	141.95 ± 13.26	133.58 ± 13.22$^{\#\#\#}$***	134.74 ± 12.95$^{\beta\beta\beta}$
HDL	46.85 ± 8.96	47.27 ± 8.33	46.3 ± 9.49	44.57 ± 9.15	47.50 ± 8.42**	47.10 ± 7.28$^{\beta}$
LDL	92.29 ± 20.98	90.65 ± 20.32	92.67 ± 19.25	97.93 ± 20.08	90.97 ± 20.37*	94.45 ± 23.43
VLDL	28.67 ± 2.41	28.914 ± 2.57	28.80 ± 2.13	28.39 ± 2.65	26.71 ± 2.64$^{\#\#\#}$***	26.94 ± 2.58$^{\beta\beta\beta}$

$^{\#}p < 0.05$; $^{\#\#}p < 0.01$; $^{\#\#\#}p < 0.001$ comparison between post control and post yoga group by unpaired t-test. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ comparison within the group with pretraining and post training by using RMANOVA; $^{\$}p < 0.05$; $^{\$\$}p < 0.01$; $^{\$\$\$}p < 0.001$ comparison between post yoga and follow-up yoga group by RMANOVA. $^{\beta}p < 0.05$; $^{\beta\beta}p < 0.01$; $^{\beta\beta\beta}p < 0.001$ comparison between pre yoga and follow-up yoga group by RMANOVA.

There was no significant difference in the lipid profile parameters of pre, post, and follow-up values of the control group. In yoga group, the post training mean values of TGL and VLDL shows significant decrease when comparing with post training control values. Post training yoga group mean values of all lipid profile parameters shows significant decrease except HDL which is significantly increases when compared with pre training yoga group. Moreover the follow-up values shows a sustained effect like post training group when compared with pretraining values except LDL.

Stress marker and Antioxidants parameters

Parameters	Control (N= 63)			Yoga (N= 61)		
	Pre	Post	Follow-up	Pre	Post	follow-up
Ox-LDL	66.36 ± 8.12	65.03 ± 8.91	65.07 ± 8.26	67.78 ± 7.13	64.90 ± 6.88**	66.00 ± 6.68
SOD	2.11 ± 0.48	2.08 ± 0.46	2.15 ± 0.35	2.13 ± 0.48	2.35 ± 0.51$^{\#\#\#}$***	2.22 ± 0.47$^{\$\$\$\beta}$
GPx	1.77 ± 0.40	1.79 ± 0.38	1.86 ± 0.45	1.91 ± 0.52	2.07 ± 0.48$^{\#\#\#}$*	1.91 ± 0.34$^{\$}$
Catalase	19.23 ± 5.62	19.89 ± 5.61	19.12 ± 3.90	18.10 ± 5.05	19.59 ± 4.27*	19.45 ± 4.55

$^{\#}p < 0.05$; $^{\#\#}p < 0.01$; $^{\#\#\#}p < 0.001$ comparison between post control and post yoga group by unpaired t-test. *p < 0.05; **p < 0.01; ***p < 0.001 comparison within the group with pretraining and post training by using RMANOVA; $^{\$}p < 0.05$; $^{\$\$}p < 0.01$; $^{\$\$\$}p < 0.001$ comparison between post yoga and follow-up yoga group by RMANOVA. $^{\beta}p < 0.05$; $^{\beta\beta}p < 0.01$; $^{\beta\beta\beta}p < 0.001$ comparison between pre yoga and follow-up yoga group by RMANOVA.

There was no significant difference in the oxidative stress marker and endogenous antioxidants parameters of pre, post, and follow-up values of the control group. In yoga group, the post training mean values of SOD and GPx shows significant increase when comparing with post training control values. Post training yoga group mean value of Ox-LDL shows significant decrease and SOD, GPx, catalase shows significantly increases when compared with pre training yoga group. The follow-up values of SOD and GPx significantly decreases when compared with post yoga group. Moreover, SOD values shows significantly increased when compared with pretraining.

Discussion

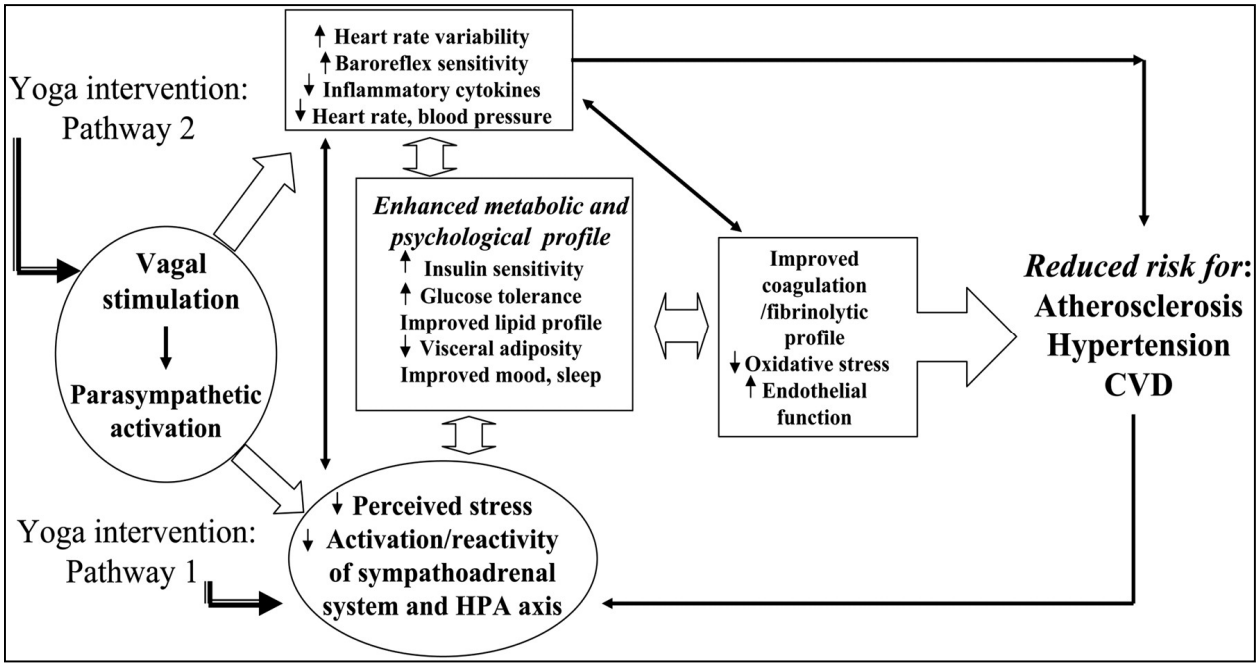
Decreased Systolic blood Pressure indicates significant decreased in sympathetic activity and/or concomitant increased in vagal activity at the end of 12 week yoga training (Ganong, 2005) in yoga group and this effect is sustaining after follow-up of yoga after 12 weeks (Follow up). Decreased Diastolic blood Pressure indicates decreased sympathetic vasoconstrictor tone at the end of 12 week yoga training (Ganong, 2005) in yoga group and this effect is sustaining after follow-up of yoga after 12 weeks (Follow up). Decreased Rate pressure product (RPP) indicates lesser workload on heart and myocardial oxygen consumption (White, 1999, Madanmohan, 2004) at the end of 12 week yoga training (Ganong, 2005) in yoga group and this effect is sustaining after follow-up of yoga after 12 weeks (Follow up).

In Heart rate variability (HRV) Time domain parameters increased in Mean RR, SDNN, RMSSD, pNN50 and decreased in Mean HR in yoga groups that shows increased cardiac vagal activity (Punita 2016) at the end of 12 week yoga training in yoga group and this effect is sustaining after follow-up of yoga after 12 weeks (Follow up).

In frequency domain increased High frequency (HF), High frequency normalization unit (HF nu), and decreased LF/HF, Low frequency normalization unit (LF nu) in yoga groups at the end of 12 weeks that shows the parasympathetic predominance and restore the sympathovagal balance in heart at the end of 12 week yoga training in yoga group and this effect is sustaining in LF nu, HF nu and not sustain in HF, LF/HF after follow-up of yoga after 12 weeks (Follow up).

Slow deep breathing stimulates Hering-Breuer inflation reflex, withdrawal of sympathetic tone leads ↓ in HR, SP & DP. (Latadevi, 2012). Proprioceptors send impulses to limbic-hypothalamic-medullary centers to enhances the vagal tone on heart. (Pal, 2004)

Stress induces the imbalance of the ANS, under activity of GABA system and increase in allostatic load. On the other side Yoga-based practices correct underactivity of vagus and GABA systems, and reduce allostatic load (Streeter, 2012). Yoga decreases the Cardiovascular risk through parasympathetic activation coupled with decreases the sympathoadrenal activity and hypothalomo-pituitary-adrenal (HPA) axis. **(Innes, 2007)**



- Decrease in Total Cholesterol, TGL, LDL, VLDL and increase in HDL at the end of 12 week yoga training in yoga group shows decreasing in developing the cardiovascular risk factors like CAD, CHD (Sarode 2017, Gadham 2015, Maini 2014, Madanmohan 2013, Pal 2011) and this effect is sustaining after follow-up of yoga after 12 weeks (Follow up) except LDL.

- Ox-LDL (Stress marker) is significantly decrease at the end of 12 week yoga training in yoga group shows decrease ventricular remodeling, vascular damage (atherosclerosis and arterial stiffness) (Rietzschel 2008), cardiovascular disease (Itabe 2007), Biochemical risk marker for CHD (Toshima 2000) and this effect is not sustaining after follow-up of yoga after 12 weeks (Follow up).

- Glutathione peroxidase (GSH-Px), SOD, and catalase (Enzymatic antioxidants) are significantly increase at the end of 12 week yoga training in yoga group shows that protect against oxidative stress (Lim SA 2015, Pal R 2015).

- SOD sustain the effect and Glutathione peroxidase and catalase is significantly decrease after follow-up of yoga after 12 weeks (Follow up).

Conclusion

- This study offers further evidence of the cardiovascular relaxation, enhance HRV afforded by regular yoga practice.
- Regular yoga practice have beneficial effect on Blood pressure, autonomic nervous system (HRV), Lipid components, oxidative stress, and enzymatic antioxidants. And these effects are decreased after quit the yoga practice.
- Regular yoga practice is recommends to reduce Blood pressure, Sympathetic activity, bad cholesterol, Oxidative stress and enhance Parasympathetic activity, HRV, good cholesterol and Antioxidants level.

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Oral presentation

1. 'SYMMEDCON" 2nd International Conference on Stress, Yoga & Mind-Body Medicine organised by Sri Ramachandra Medical College and Research Institute, Chennai. On Jan 30th & 31st 2018.
2. "TABSCON-D 2019" National Conference on basic medical sciences organised by Department of Basic Medical Sciences, Tagore Dental College and Hospital on Jan 29th & 30th 2019.

Publications:

1. Uthiravelu P, Vasanthan S, Bhavanani AB, Hanifah M, Ramesh R, Jaiganesh K. Effect Of 12 Weeks Yoga Training And 12 Weeks Detraining on Heart Rate Variability on Subjects with Hypertension. Journal of Advanced Zoology. 2023 Sep 4;44.

2. Uthiravelu P, Vasanthan S, Bhavanani AB, Hanifah M, Ramesh R, Jaiganesh K. Effect Of 12 Weeks Yoga Training And 12 Weeks Detraining on Blood Pressure Subjects with Hypertension. Journal of Advanced Zoology. 2023 Sep 4;44.